US012174309B2

(12) **United States Patent**
Meidan et al.

(10) **Patent No.: US 12,174,309 B2**
(45) **Date of Patent: Dec. 24, 2024**

(54) **SYSTEM AND METHOD FOR CLASSIFYING A TYPE OF INTERACTION BETWEEN A HUMAN USER AND A MOBILE COMMUNICATION DEVICE IN A VOLUME BASED ON SENSOR FUSION**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 55 days.

(21) Appl. No.: **17/679,204**

(22) Filed: **Feb. 24, 2022**

(65) **Prior Publication Data**

US 2023/0027582 A1 Jan. 26, 2023

Related U.S. Application Data

(60) Provisional application No. 63/223,980, filed on Jul. 21, 2021.

(51) **Int. Cl.**
G01S 5/02 (2010.01)
B60N 2/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G01S 5/0289*** (2013.01); ***B60N 2/002*** (2013.01); ***B60R 21/01516*** (2014.10);
(Continued)

(58) **Field of Classification Search**
CPC G01S 5/0289; G01S 5/06; G01S 13/589; G01S 13/931; B60R 21/01516; B60N 2/002; B60W 40/09; B60W 40/13
See application file for complete search history.

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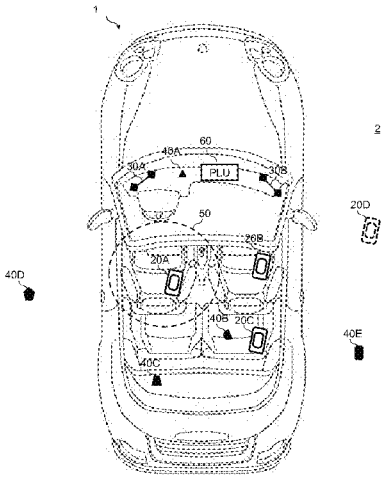
(57) **ABSTRACT**

A system and method for classifying a type of interaction between a human user and a mobile communication device within a defined volume, based on multiple sensors. The method may include: determining a position of the mobile communication device relative to a frame of reference of the defined volume, based on: angle of arrival, time of flight, or received intensity of radio frequency (RF) signals transmitted by the mobile communication device and received by a phone location unit located within the defined volume configured to wirelessly communicate with the mobile communication device; obtaining at least one sensor measurement related to the mobile communication device from various non-RF sensors; repeating the obtaining, to yield a time series of sensor readings; and using a computer processor to classify the type of interaction into one of many predefined types of interactions, based on the position and the time series of sensor readings.

24 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

B60R 21/015	(2006.01)
B60W 40/08	(2012.01)
B60W 40/09	(2012.01)
B60W 40/13	(2012.01)
G01S 5/06	(2006.01)
G01S 13/58	(2006.01)
G01S 13/931	(2020.01)

(52) **U.S. Cl.**

CPC ***B60W 40/09*** (2013.01); ***B60W 40/13*** (2013.01); ***G01S 5/021*** (2013.01); ***G01S 5/06*** (2013.01); ***G01S 13/589*** (2013.01); ***G01S 13/931*** (2013.01); *B60W 2040/0863* (2013.01); *B60W 2040/0872* (2013.01); *B60W 2040/0881* (2013.01); *B60W 2040/1353* (2013.01); *B60W 2540/01* (2020.02); *B60W 2540/221* (2020.02); *B60W 2540/227* (2020.02); *B60W 2540/229* (2020.02); *G01S 2013/932* (2020.01); *G01S 2013/9322* (2020.01)

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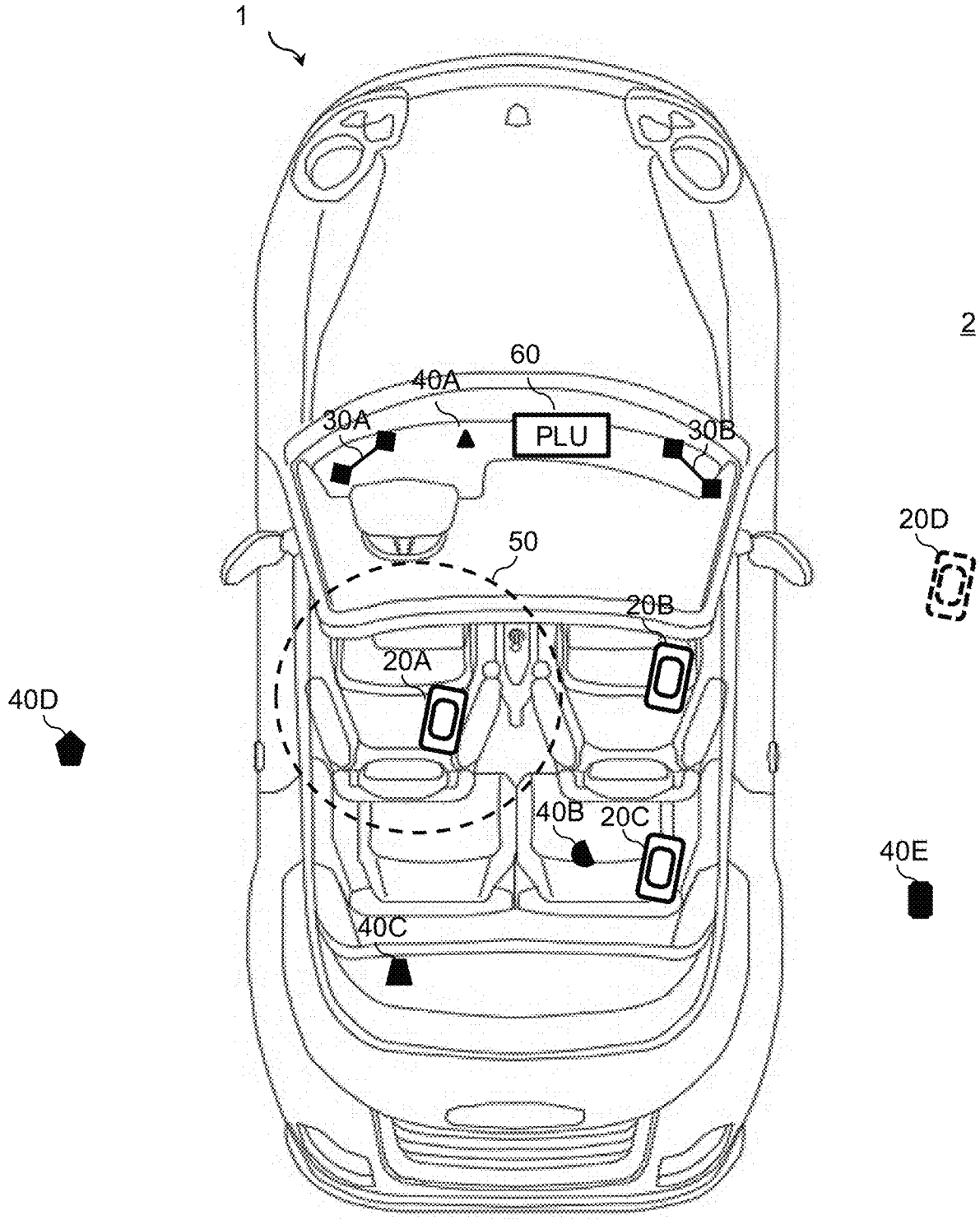

Figure 1

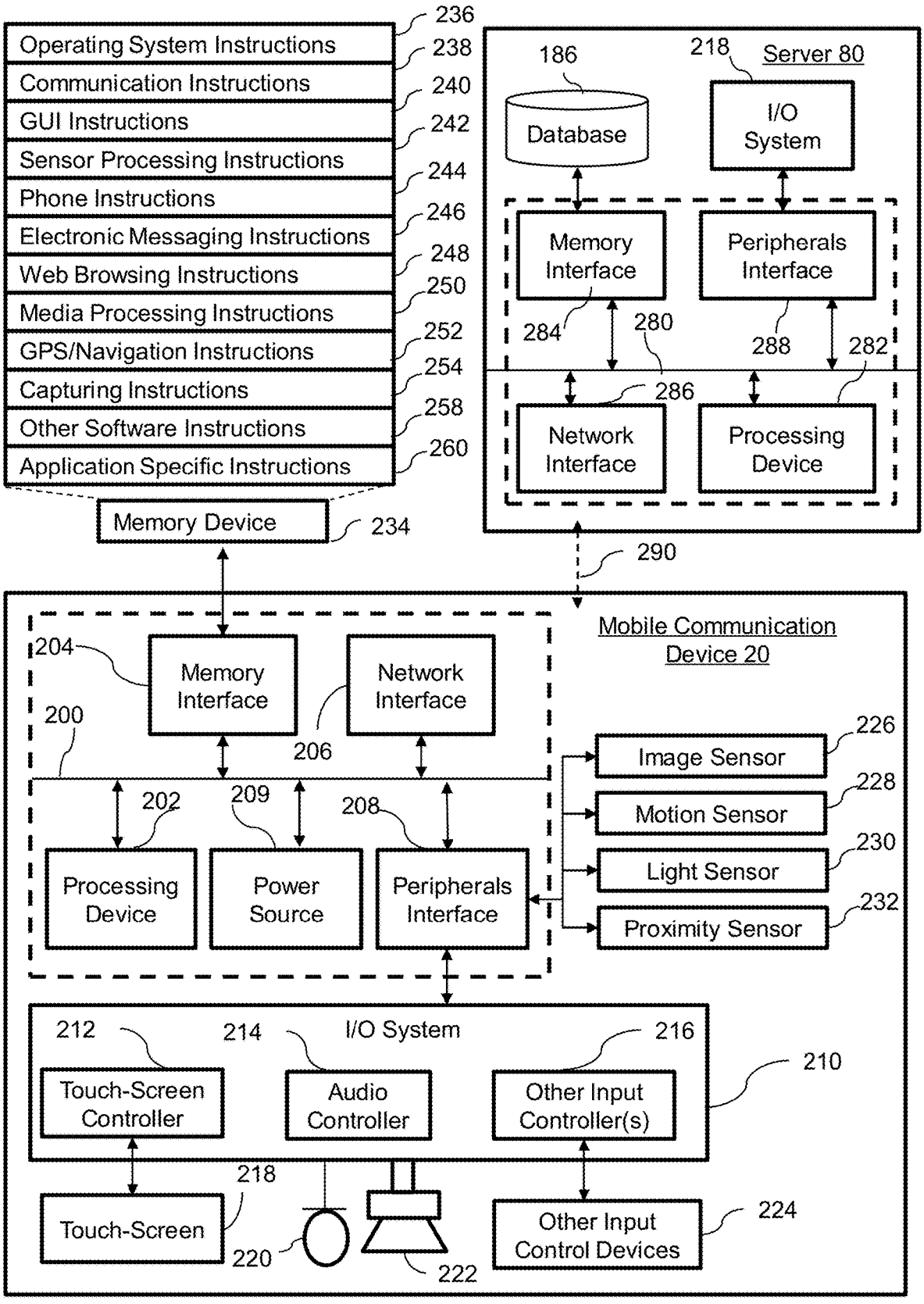
Operating System Instructions
Communication Instructions
GUI Instructions
Sensor Processing Instructions
Phone Instructions
Electronic Messaging Instructions
Web Browsing Instructions
Media Processing Instructions
GPS/Navigation Instructions
Capturing Instructions
Other Software Instructions
Application Specific Instructions
236
238
240
242
244
246
248
250
252
254
258
260
Memory Device
234
186
Database
218
Server 80
I/O System
Memory Interface
Peripherals Interface
284
280
288
282
286
Network Interface
Processing Device
290
Mobile Communication Device 20
204
Memory Interface
Network Interface
200
206
202
209
208
Processing Device
Power Source
Peripherals Interface
Image Sensor
Motion Sensor
Light Sensor
Proximity Sensor
226
228
230
232
212
214
I/O System
216
210
Touch-Screen Controller
Audio Controller
Other Input Controller(s)
218
Touch-Screen
220
222
Other Input Control Devices
224

Figure 2A

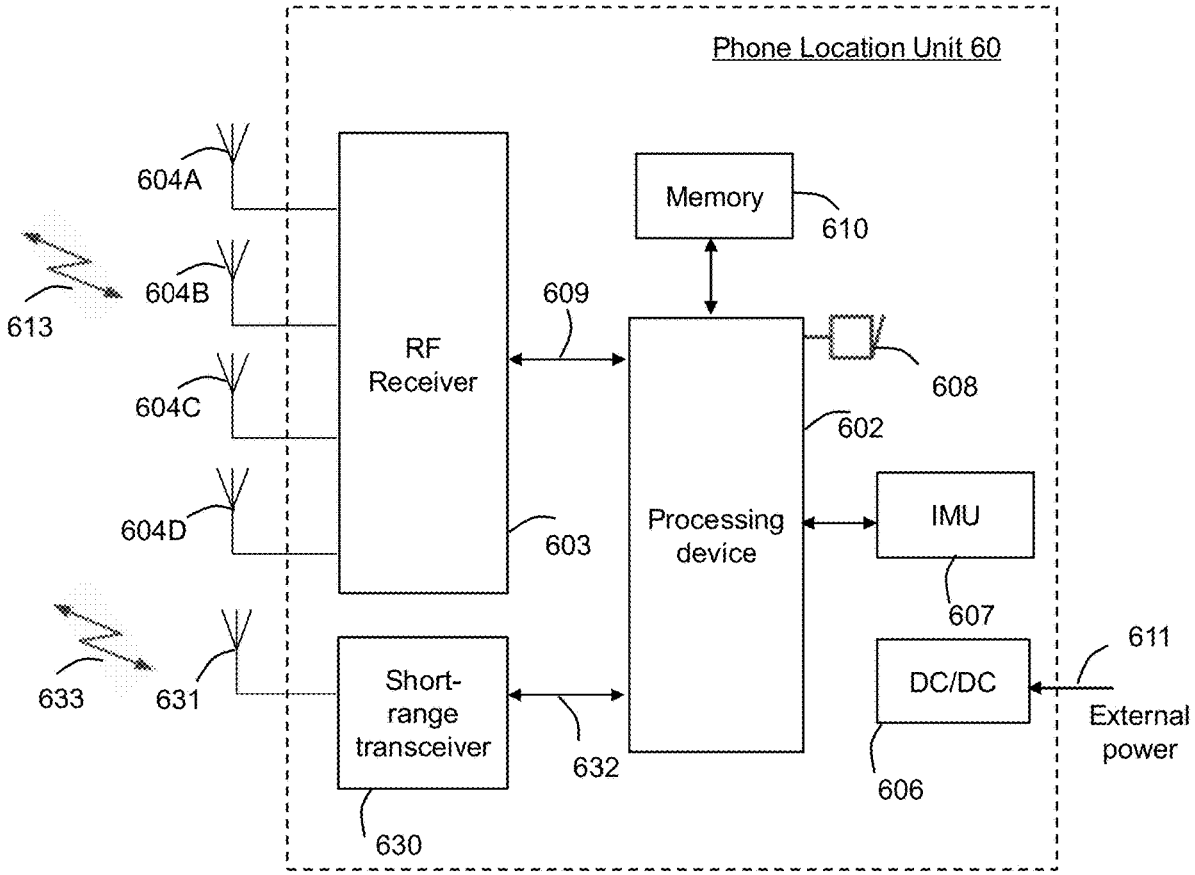
Phone Location Unit 60
604A
604B
613
604C
604D
633
631
RF Receiver
609
603
Memory
610
608
602
Processing device
IMU
607
611
DC/DC
External power
606
Short-range transceiver
632
630

Figure 2B

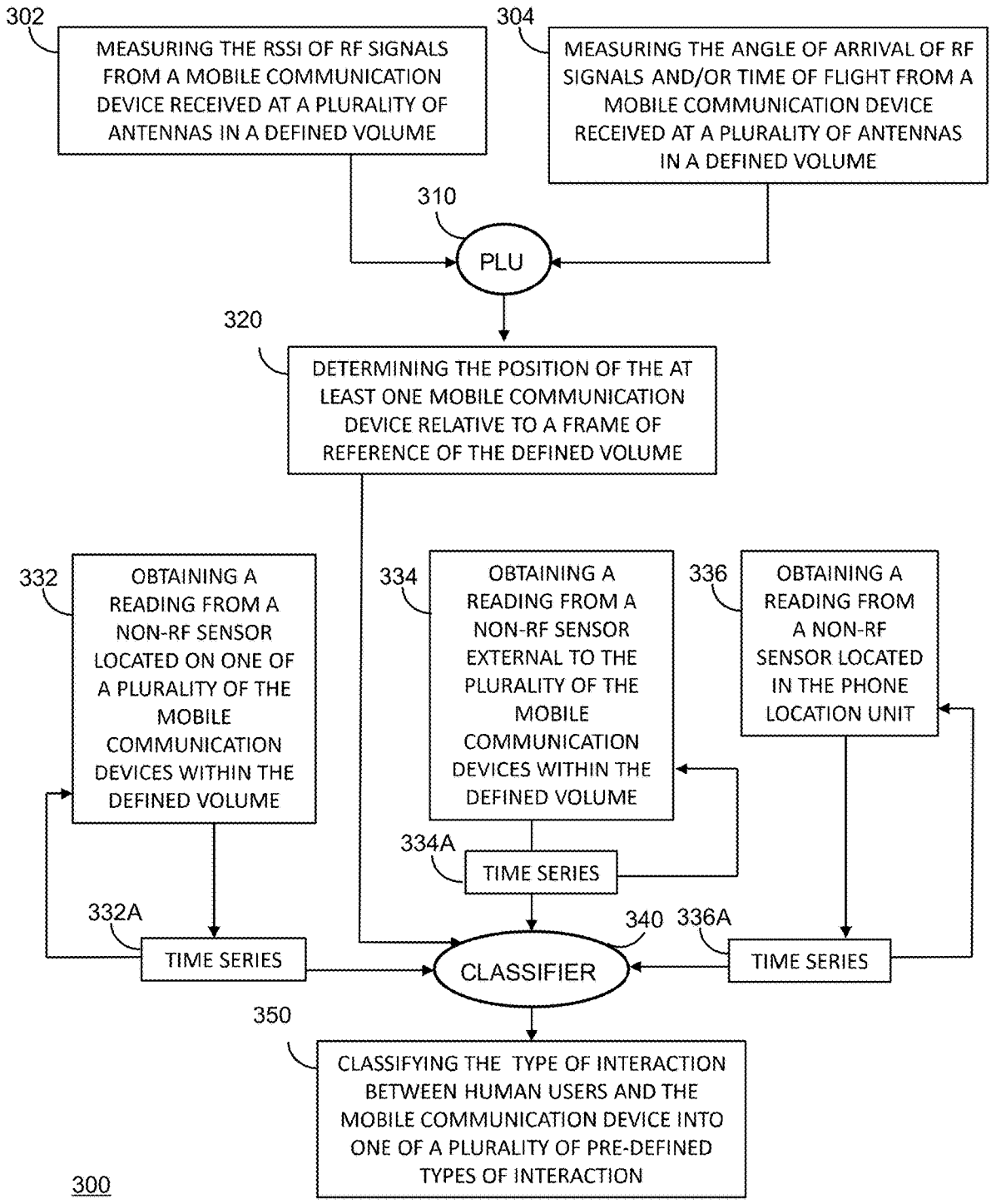
302
MEASURING THE RSSI OF RF SIGNALS FROM A MOBILE COMMUNICATION DEVICE RECEIVED AT A PLURALITY OF ANTENNAS IN A DEFINED VOLUME
304
MEASURING THE ANGLE OF ARRIVAL OF RF SIGNALS AND/OR TIME OF FLIGHT FROM A MOBILE COMMUNICATION DEVICE RECEIVED AT A PLURALITY OF ANTENNAS IN A DEFINED VOLUME
310
PLU
320
DETERMINING THE POSITION OF THE AT LEAST ONE MOBILE COMMUNICATION DEVICE RELATIVE TO A FRAME OF REFERENCE OF THE DEFINED VOLUME
332
OBTAINING A READING FROM A NON-RF SENSOR LOCATED ON ONE OF A PLURALITY OF THE MOBILE COMMUNICATION DEVICES WITHIN THE DEFINED VOLUME
334
OBTAINING A READING FROM A NON-RF SENSOR EXTERNAL TO THE PLURALITY OF THE MOBILE COMMUNICATION DEVICES WITHIN THE DEFINED VOLUME
336
OBTAINING A READING FROM A NON-RF SENSOR LOCATED IN THE PHONE LOCATION UNIT
334A
TIME SERIES
332A
TIME SERIES
340
CLASSIFIER
336A
TIME SERIES
350
CLASSIFYING THE TYPE OF INTERACTION BETWEEN HUMAN USERS AND THE MOBILE COMMUNICATION DEVICE INTO ONE OF A PLURALITY OF PRE-DEFINED TYPES OF INTERACTION
300

Figure 3

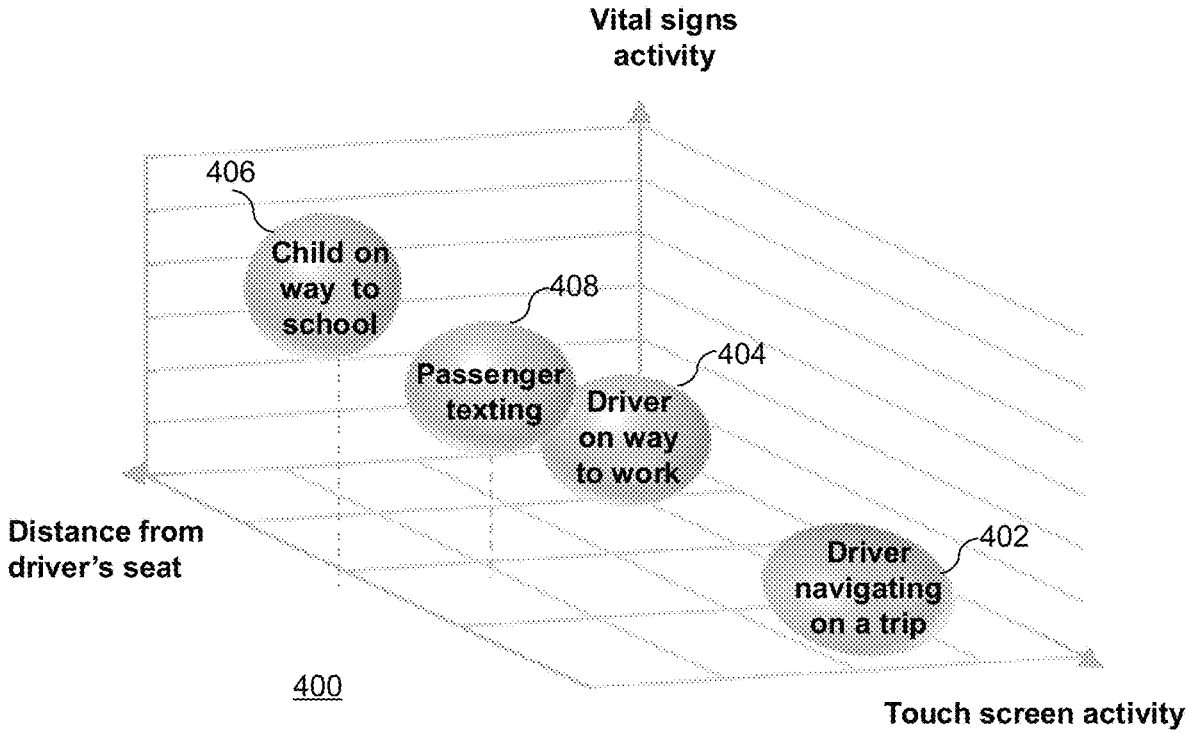
Vital signs activity
406
Child on way to school
408
Passenger texting
404
Driver on way to work
Distance from driver's seat
402
Driver navigating on a trip
400
Touch screen activity

Figure 4

SYSTEM AND METHOD FOR CLASSIFYING A TYPE OF INTERACTION BETWEEN A HUMAN USER AND A MOBILE COMMUNICATION DEVICE IN A VOLUME BASED ON SENSOR FUSION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Patent Application No. 63/223,980, filed on Jul. 21, 2021, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention relates generally to the field of signal processing, and more particularly to using sensor fusion to classify signals of various types concerning a mobile communication device.

BACKGROUND OF THE INVENTION

Automatically locating a mobile communication device within a defined volume is known in the art and has many applications. One known application refers to determining whether a mobile communication device is being used by a driver of a moving vehicle. Such a solution is described in U.S. Pat. No. 10,075,581 which is incorporated herein by reference in its entirety. Further improvements to the localization of a mobile communication device within a defined volume have been described in U.S. Pat. No. 10,557,917 which is also incorporated herein by reference in its entirety.

As mobile communication devices have several types of interaction as described hereinafter, it would be further advantageous to know, in addition to the location of the mobile communication device, also its type of interaction, in order to determine the overall driving safety.

SUMMARY OF THE INVENTION

In order to address the aforementioned challenges, it has been suggested by the inventors of the present invention to introduce a sensor fusion approach to the aforementioned classification problem. In addition to the localization data received using known technologies, a plurality of sensors, internal to the mobile communication device or external to it, are used together to deduce the type of interaction between a human user and the mobile communication device.

According to some embodiments, the type of interaction classification may further include information about a human user interacting with the mobile communication device. For example, there is a significant difference if a mobile communication device in texting mode is interacting with a bus driver, or a passenger seated at the back seat of the vehicle.

Some embodiments of the present invention provide a system and a method for classifying the type of interaction between a human user and at least one mobile communication device within a defined volume, based on multiple sensors are provided herein. The method may include the following steps: determining a position of the at least one mobile communication device relative to a frame of reference of the defined volume, based on at least one of: angle of arrival, time of flight such as Round Trip Time (RTT) and Time Difference Of Arrival (TDOA), or received intensity of

radio frequency (RF) signals transmitted by the at least one mobile communication device and received by a phone location unit located within the defined volume and comprising a transceiver and antennas and further configured to wirelessly communicate with the at least one mobile communication device; obtaining at least one sensor measurement related to the at least one mobile communication device, from a sensor located on at least one of: the at least one mobile communication device, within the defined volume, or outside of the defined volume; repeating the obtaining over time to yield at least one time series of sensor readings; and using a computer processor to classify the type of interaction between the human user and the at least one mobile communication device into at least one of a plurality of predefined types of interaction of the mobile communication device, based on the position and the at least one time series of sensor readings.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter regarded as the invention is particularly pointed out and distinctly claimed in the concluding portion of the specification. The invention, however, both as to organization and method of operation, together with objects, features, and advantages thereof, may best be understood by reference to the following detailed description when read with the accompanying drawings in which:

FIG. **1** is a high-level block diagram illustrating a deployment of the system in accordance with embodiments of the present invention;

FIG. **2**A is a detailed block diagram illustrating an exemplary architecture of a mobile communication device in communication with a server in accordance with some embodiments of the present invention;

FIG. **2**B is a detailed block diagram illustrating an exemplary architecture of a phone location unit in accordance with some embodiments of the present invention; and

FIG. **3** is a high-level flowchart illustrating a method for classifying types of interaction of a mobile communication device in accordance with embodiments of the present invention; and

FIG. **4** is a graph showing an implementation of an N-dimensions classifier in accordance with some embodiments of the present invention.

It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference numerals may be repeated among the figures to indicate corresponding or analogous elements.

DETAILED DESCRIPTION OF THE INVENTION

Prior to setting forth the detailed description of the invention, it may be helpful to provide herein definitions of certain terms that will be used hereinafter.

The terms "volume", "defined volume" or "closed volume" as used herein are defined as any well-defined volume with boundaries that can be set or detected. The volume is typically a vehicle such as a car, train, airplane, ship, but can also be a motorbike or any other moving platform. The volume can also relate to a room such as a conference room, a theater, and the like. The defined volume herein is in contrast with an open space whose boundaries cannot be easily defined.

The term "mobile communication device" as used herein is defined as any electronic device which is small enough to be carried by a human user and further has radio frequency (RF) wireless communication capabilities. The mobile communication device is typically a phone such as a smartphone, a smartwatch, a laptop, a tablet, or a game console. The mobile communication device may support audio calls or transmitting and receiving data and may or not have a touch screen.

The term "phone location unit" or PLU as used herein is defined as a hardware-based device typically including a set of RF receiving antennas placed in a known location within the defined volume, a receiver, and a computer processor. The PLU can locate a mobile communication device based on processing the RF signals received by its antennas.

The term "type of interaction" as used herein is defined as the type of interaction between a human user and at least one mobile communication device and may relate to the I/O functionalities of the mobile communication device that are being applied over a specific time segment. It should be noted that a "type of interaction" between a human user and a mobile communication device differs from a "mode of operation" of the mobile communication device in that an interaction requires machine-user interaction to be recorded over time whereas a mode of operation does not require interaction at all and can be derived and deduced instantly. Furthermore, while a "mode of operation" is focused on the mobile communication device itself, the "type of interaction" is further focused on the human user and his or her activities.

Some types of interaction are listed herein by means of a non-exhaustive list: A "non-engagement" type of interaction is defined where the mobile communication device is turned on, but the human user has no interaction with it via the I/O functionalities. An "audio engagement" type of interaction is defined whenever an audio call of any type is taking place which requires the use of a microphone, speaker, headphones. Another type of "audio engagement" may only require the use of a speaker or headphones or audio operation (e.g., listening to a recorded message, podcast, etc.). A "visual engagement" type of interaction is defined as any use of screen functionality such as browsing functionalities of the mobile communicating device, including the use of any email application. A type of interaction "audiovisual" is when the human user is identified as engaged in a video conference or interactive game. As the interaction is monitored over time, some more specific types of interaction can be identified as part of a pattern, such as "driving to work", and "picking up a child from nursery". These are more specific types of interaction that may infer on the activity of the bearer of the mobile communication device and not just the phone itself. Such an activity can also be referred to as a "routine activity" or a "non-routine activity". Thus, more insight can be derived from monitoring the interaction with the mobile communication device over time.

In the following description, various aspects of the present invention will be described. For purposes of explanation, specific configurations and details are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to one skilled in the art that the present invention may be practiced without the specific details presented herein. Furthermore, well-known features may be omitted or simplified in order not to obscure the present invention.

Unless specifically stated otherwise, as apparent from the following discussions, it is appreciated that throughout the specification discussions utilizing terms such as "processing", "computing", "calculating", "determining", or the like, refer to the action and/or processes of a computer or computing system, or similar electronic computing device, that manipulates and/or transforms data represented as physical, such as electronic, quantities within the computing system's registers and/or memories into other data similarly represented as physical quantities within the computing system's memories, registers or other such information storage, transmission or display devices.

FIG. **1** is a block diagram illustrating a system for classifying a type of interaction of at least one mobile communication device **20**A-**20**C within a defined or closed volume, such as car **1**, based on multiple sensors **40**A, **40**B, **40**C, **40**D, **40**E located either within or outside the defined volume or on various mobile communication devices located within or outside the defined volume. A phone location unit (PLU) **60** is located within the defined volume and is configured to determine the position of the at least one mobile communication device **20**A-**20**C relative to a frame of reference of defined volume **1** and specifically allows determining whether any of mobile communication devices **20**A-**20**C are located within an area defined as the driver's canopy **50**.

According to some embodiments of the present invention, the localization of the mobile communication device **20**A-**20**C by PLU **60** may be based on at least one of: angle of arrival (e.g., using directional antennas, monopulse antennas, antenna arrays, etc.), time of flight (e.g., using UWB round trip time measurements), or received intensity of radio frequency (RF) signals transmitted by the at least one mobile communication device **20**A-**20**C and received by the PLU **60** which may include a transceiver (not shown) and at least two pairs of antennas **30**A, **30**B and further configured to wirelessly communicate with the at least one mobile communication device **20**A-**20**C.

According to some embodiments of the present invention, the system may include a plurality of sensors **40**A, **40**B, **40**C which are either installed as part of car **1** or can be retrofitted once the system is installed on car **1**. The system may be configured to obtain at least one sensor measurement, possibly via a wireless communication with PLU **60**, such measurements being related to the at least one mobile communication device **20**A-**20**C. These sensors may be located on at least one of: the at least one mobile communication device **20**A-**20**C, within the defined volume **1**, for example, sensors **40**A, **40**B, **40**C, or outside **2** of the defined volume, for example, sensors **40**D and **40**E which can be sensors on mobile communication devices in other vehicles which are sufficiently close to the system and can communicate with it. In some embodiments, sensors **40**D and **40**E may be imaging sensors which are installed outside the vehicle, and which may provide information related to the type of interaction.

According to some embodiments, the defined volume **1** is any type of vehicle such as a car, train, airplane, ship, but can also be a motorbike or any other moving platform. According to some embodiments of the present invention, the system may further include a computer processor, or a computing device (not shown here) configured to classify the interaction of the human user with at least one mobile communication device **20**A-**20**C into at least one of a plurality of predefined types of interaction, based on the calculated position and the at least one sensor reading, preferably in times series form.

According to some embodiments of the present invention, the classification by the computer processor is carried out by assigning to the at least one mobile communication device

a respective likelihood, to at least one type of interaction selected from a plurality of types of interaction.

According to some embodiments of the present invention, the system may obtain readings from at least two inertial measurement units (IMU) wherein at least one of the IMUs is located on the at least one mobile communication device **20**A-**20**C and at least one of the IMUs is located anywhere within the car such as on a vehicle IMU **40**A or alternatively an IMU of PLU **60**. The inertial sensors readings may be subtracted to yield a differential measurement which can be used to deduce internal movement of the at least one mobile communication device **20**A-**20**C within the vehicle **1**.

According to some embodiments of the present invention, the position of the mobile communication unit within the defined volume is further determined to be in the vehicle's driver area, wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a motion sensor **40**A, said sensor providing information related to the vehicle's speed and wherein the vehicle's speed is factored in classifying the likelihood of the type of interaction, wherein for a mobile communication device located in the driver's area referred to as driver's canopy **50**, a higher speed may infer a higher probability of non-engagement type of interaction or a type of interaction not involving the manual intervention of the user (e.g., texting).

In other cases, and according to some embodiments, the mobile communication device **20**A-**20**C may be located in the back seat area, and that infers a lower probability of a phone call using a fixed cradle. A mobile communication device **20**A-**20**C on a fixed cradle (not shown) may be identified by correlating measurements from an inertial sensor in the mobile device **20**C and measurements from an inertial sensor in the vehicle **40**A and/or the phone location unit **60**.

According to some embodiments of the present invention, inside the vehicle there is at least one human user, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a proximity sensor, said proximity sensor providing information on the proximity between the at least one mobile communication device and the at least one human user, and wherein the proximity is factored in classifying the likelihood of the type of interaction, wherein a closer proximity may infer a higher probability of an audio engagement type of interaction.

As may be apparent to one skilled in the art, the estimated location of the mobile communication device in the vehicle may affect the likelihood of one or more types of interaction. For example, the combination of the proximity sensor and a location far from the driver's area may infer that an audio/visual engagement is being performed by a vehicle's passenger.

According to some embodiments of the present invention, inside the vehicle there is at least one human user, and wherein the vehicle comprises at least one seat with a pressure sensor **40**B indicating that said seat is occupied by the at least one human user, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a seat pressure sensor and wherein the seat pressure sensor indication is factored in classifying the likelihood of the type of interaction, wherein a positive indication of a seat pressure sensor may infer a higher probability of engagement of a mobile communication device by a human user occupying that seat.

According to some embodiments, the estimated location of the mobile communication unit is further combined with measurements from several sensor types. For example, seat pressure sensors indicating seat occupancy in both the driver's seat and a back seat in a car, together with an indication of proximity between the mobile communication device and a human user and an estimated location in the front seats, may significantly increase the probability of a phone call being performed by a driver with a unit on-hand. According to some embodiments, the likelihood of this type of interaction can be further increased (or decreased) by using measurements from inertial sensors as previously disclosed.

According to some embodiments of the present invention, inside the vehicle there is at least one human user, and wherein the at least one human user is sensed by at least one vital signs sensor, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from at least one vital signs sensor and wherein a vital signs measurement is factored in classifying the likelihood of the type of interaction, wherein a level of vital signs outside (i.e., above or below) a certain threshold or limit infers a higher probability of a non-idle type of interaction of the at least one mobile communication device. For example, and according to some embodiments, vital signs measurements which may include heart rate, heart rate variability. For example, the standard deviation of all normal-to-normal R-R intervals-SDNN and root mean square of successive differences between normal-to-normal R-R intervals—(rMSSD data), blood pressure, respiration rate and pulse-respiration quotient (PRQ), sympathetic stress, parasympathetic activity, etc. may help in detecting some activities related to mobile phone usage such texting while driving, the distraction of the user (e.g., driver), and the like.

According to some embodiments, the phone location unit may keep the history of measurements related to the driver's vital signs (e.g., average heart rate and heart rate variability) and may correlate them with new measurements. According to some embodiments, this correlation may allow better identification of the driver and increase the probability of interaction types related to the driver. When combined with measurements from other sensors (e.g., seat sensors), and the mobile communication unit location, special interaction types may be detected (e.g., a driver's distress mode using his or her phone to request assistance).

FIG. **2**A shows an exemplary block diagram of the configuration of a server **80** and a mobile communication device **20**. According to some embodiments of the present invention, a server **80** for classifying a type of interaction of at least one mobile communication device **20** within a defined volume, based on the mobile communication device position and at least one sensor, is illustrated herein.

In one embodiment, server **80**, directly or indirectly, may access a bus **280** (or another data transfer mechanism) that interconnects subsystems and components for transferring information within the server **80**. For example, **280** may interconnect a processing device **282**, a memory interface **284**, a network interface **286**, a peripherals interface **288** connected to I/O system **218**. The server **80** may comprise a power source (not shown).

Server **80** may include a network interface **266** configured to receive, from a phone location unit **60** (not shown in FIG. **2**A), the position of the at least one mobile communication device **20** relative to a frame of reference of the defined volume, based on at least one of: angle of arrival, time of flight, or received intensity of radio frequency (RF) signals transmitted by the at least one mobile communication device and received by the phone location unit located within the

defined volume and comprising a transceiver and antennas and further configured to wirelessly communicate with the at least one mobile communication device.

Server **80** may further include an interface **284** to a memory configured to store at least one sensor measurement related to the at least one mobile communication device, from a sensor located on at least one of: the at least one mobile communication device, the phone location unit, within the defined volume, or outside of the defined volume.

The server **80** may further include a processing device **282** configured to classify the at least one mobile communication device **20** into at least one of a plurality of predefined types of interaction of the mobile communication device, based on the position and at least one sensor reading.

Processing device **282** may include at least one processor configured to execute computer programs, applications, methods, processes, or other software to perform embodiments described in the present disclosure. For example, the processing device may include one or more integrated circuits, microchips, microcontrollers, microprocessors, all or part of a central processing unit (CPU), graphics processing unit (GPU), digital signal processor (DSP), field-programmable gate array (FPGA), or other circuits suitable for executing instructions or performing logic operations. The processing device may include at least one processor configured to perform functions of the disclosed methods. The processing device may include a single-core or multiple core processors executing parallel processes simultaneously. In one example, the processing device may be a single-core processor configured with virtual processing technologies. The processing device may be implemented using a virtual machine architecture or other methods that provide the ability to execute, control, run, manipulate, store, etc., multiple software processes, applications, programs, etc. In another example, the processing device may include a multiple-core processor architecture (e.g., dual, quad-core, etc.) configured to provide parallel processing functionalities to allow a device associated with the processing device to execute multiple processes simultaneously. It is appreciated that other types of processor architectures could be implemented to provide the capabilities disclosed herein.

In some embodiments, processing device **282** may use a memory interface **284** to access data and a software product stored on a memory device or a non-transitory computer-readable medium or to access a data structure **186**. As used herein, a non-transitory computer-readable storage medium refers to any type of physical memory on which information or data readable by at least one processor can be stored. Examples include random access memory (RAM), read-only memory (ROM), volatile memory, nonvolatile memory, hard drives, CD ROMs, DVDs, flash drives, disks, any other optical data storage medium, a PROM, an EPROM, a FLASH-EPROM or any other flash memory, NVRAM, a cache, a register, any other memory chip or cartridge, and networked versions of the same. The terms "memory" and "computer-readable storage medium" may refer to multiple structures, such as a plurality of memories or computer-readable storage mediums located within the server **80**, or at a remote location. Additionally, one or more computer-readable storage mediums can be utilized in implementing a computer-implemented method. The term "computer-readable storage medium" should be understood to include tangible items and exclude carrier waves and transient signals.

According to some embodiments, the network interface **286** may provide two-way data communication to a network. In FIG. **2**A, the communication **290** between the mobile communication device **20** and server **80** is represented by a dashed arrow. In one embodiment, the network interface **286** may include an integrated services digital network (ISDN) card, cellular modem, satellite modem, or a modem to provide a data communication connection over the Internet. As another example, the network interface **286** may include a wireless local area network (WLAN) card. In another embodiment, the network interface **286** may include an Ethernet port connected to radio frequency receivers and transmitters. The specific design and implementation of the network interface **286** may depend on the communications network(s) over which the mobile communication device **20** and the server **80** may communicate.

According to some embodiments, the server **80** may also include a peripherals interface **288** coupled to the bus **280**. The peripherals interface **288** may also be connected to devices, and subsystems to facilitate multiple functionalities as performed by the server **80**. In some embodiments, those devices and subsystems may comprise a display screen (e.g., CRT or LCD) a USB port, and the like.

With regard to the mobile communication device **20**, and according to some embodiments, the mobile communication device **20**, directly or indirectly, may access a bus **200** (or another data transfer mechanism) that interconnects subsystems and components for transferring information within the mobile communication device **20**. For example, bus **200** may interconnect a processing device **202**, a memory interface **204**, a network interface **206**, a peripherals interface **208** connected to I/O system **210**. A power source **209** provides the power to the mobile communication device and it may include a primary or a rechargeable battery (not shown), DC-DC converters (not shown) and other components required for the proper operation of the device **20**.

Processing device **202** may include at least one processor configured to execute computer programs, applications, methods, processes, or other software to perform embodiments described in the present disclosure. For example, the processing device **202** may include one or more integrated circuits, microchips, microcontrollers, microprocessors, all or part of a central processing unit (CPU), graphics processing unit (GPU), digital signal processor (DSP), field-programmable gate array (FPGA), or other circuits suitable for executing instructions or performing logic operations. The processing device **202** may include at least one processor configured to perform functions of the disclosed methods. The processing device may include a single-core or multiple core processors executing parallel processes simultaneously. In one example, the processing device may be a single-core processor configured with virtual processing technologies. The processing device may be implemented using a virtual machine architecture or other methods that provide the ability to execute, control, run, manipulate, store, etc., multiple software processes, applications, programs, etc. In another example, the processing device may include a multiple-core processor architecture (e.g., dual, quad-core, etc.) configured to provide parallel processing functionalities to allow a device associated with the processing device to execute multiple processes simultaneously. It is appreciated that other types of processor architectures could be implemented to provide the capabilities disclosed herein.

In some embodiments, processing device **202** may use a memory interface **204** to access data and a software product stored on a memory device or a non-transitory computer-readable medium. For example, processing device **202** may use a memory interface **204** to access a memory device **234**. As used herein, a non-transitory computer-readable storage medium refers to any type of physical memory on which

information or data readable by at least one processor can be stored. Examples include random access memory (RAM), read-only memory (ROM), volatile memory, nonvolatile memory, hard drives, CD ROMs, DVDs, flash drives, disks, any other optical data storage medium, a PROM, an EPROM, a FLASH-EPROM or any other flash memory, NVRAM, a cache, a register, any other memory chip or cartridge, and networked versions of the same. The terms "memory" and "computer-readable storage medium" may refer to multiple structures, such as a plurality of memories or computer-readable storage mediums located within mobile communication device **20** or at a remote location. Additionally, one or more computer-readable storage mediums can be utilized in implementing a computer-implemented method. The term "computer-readable storage medium" should be understood to include tangible items and exclude carrier waves and transient signals.

According to some embodiments, the network interface **206** may provide two-way data communication to a wireless network. In one embodiment, the network interface **206** may include an integrated services digital network (ISDN) card or module, cellular modem, satellite modem, or a modem to provide a data communication connection over the Internet. As another example, the network interface **206** may include a wireless local area network (WLAN) card or module. For example, in some embodiments, the network interface **206** is designed to operate over a Wi-Fi or Bluetooth® networks. In another embodiment, the network interface **206** may include an Ethernet port connected to radio frequency receivers and transmitters and in some embodiments also connected to optical (e.g., infrared) receivers and transmitters. The specific design and implementation of the network interface **206** may depend on the communications network(s) over which the mobile communication device **20** is intended to operate. In any such implementation, the network interface **206** may be configured to send and receive electrical, electromagnetic, or optical signals that carry digital data streams representing various types of information.

According to some embodiments, the peripherals interface **208** may also be connected to sensors, devices, and subsystems to facilitate multiple functionalities. In one embodiment, the peripherals interface **208** may be connected to an I/O system **210** configured to receive signals or input from devices and to provide signals or output to one or more devices that allow data to be received and/or transmitted by the mobile communication device **20**. In one example, the I/O system **210** may include a touch screen controller **212**, audio controller **214**, and/or other types of input controller(s) **216**. The touch screen controller **212** may be coupled to a touch screen **218**. The touch screen **218** and the touch screen controller **212** may, for example, detect contact, movement, using any of a plurality of touch sensitivity technologies, including but not limited to capacitive, resistive, infrared, and surface acoustic wave technologies as well as other proximity sensor arrays or other elements for determining one or more points of contact with the touch screen **218**. The touch screen **218** may also, for example, be used to implement virtual or soft buttons and/or a keyboard. While a touch screen **218** is shown in FIG. **2***a*, I/O system **210** may include a display screen (e.g., LCD or LED) in place of a touch screen **218**. The audio controller **214** may be coupled to a microphone **220** and to a speaker **222** to facilitate voice-enabled functions, such as voice recognition, voice replication, digital recording, and telephony functions. The other input controller(s) **216** may be coupled to other input/control devices **224**, such as one or more buttons, rocker switches, thumbwheel, infrared port, USB port, and/or a pointer device such as a stylus.

According to some embodiments, the peripherals interface **208** may also be connected to an image sensor **226**, a motion sensor **228**, a light sensor **230**, and/or a proximity sensor **232** to facilitate image capturing, orientation, lighting, and proximity functions. Other sensors (not shown) may also be connected to the peripherals interface **208**, such as a temperature sensor, a biometric sensor, or other sensing devices that facilitate related functionalities. In addition, a GPS receiver may also be integrated with, or connected to, the mobile communication device **20**, such as GPS receivers typically integrated into mobile communications devices. Alternatively, GPS software may permit the mobile communication device **20** to access an external GPS receiver (e.g., connecting via a serial port or Bluetooth).

Consistent with the present disclosure, the mobile communication device **20** may use a memory interface **204** to access a memory device **234**. The memory device **234** may include high-speed random-access memory and/or nonvolatile memory such as one or more magnetic disk storage devices, one or more optical storage devices, and/or flash memory (e.g., NAND, NOR). The memory device **234** may store an operating system **236**, such as Android, iOS, MS Windows, Linux, or any other embedded operating system. The operating system **236** may include instructions for handling basic system services and for performing hardware-dependent tasks. In some implementations, the operating system **236** may be a kernel (e.g., Linux kernel).

The memory device **234** may also store communication instructions **238** to facilitate communicating with one or more additional devices, one or more computers, and/or one or more servers. The memory device **234** may include: graphical user interface instructions **240** to facilitate graphic user interface processing; sensor processing instructions **242** to facilitate sensor-related processing and functions; phone instructions **244** to facilitate phone-related processes and functions; electronic messaging instructions **246** to facilitate electronic-messaging related processes and functions; web browsing instructions **248** to facilitate web browsing-related processes and functions; media processing instructions **250** to facilitate media processing-related processes and functions; GPS/navigation instructions **252** to facilitate GPS and navigation-related processes and instructions; capturing instructions **254** to facilitate processes and functions related to image sensor **226**; and/or other software instructions **258** to facilitate other processes and functions.

Each of the above-identified instructions and applications may correspond to a set of instructions for performing one or more functions described above. These instructions do not necessarily need to be implemented as separate software programs, procedures, or modules. The memory device **234** may include additional instructions or fewer instructions. Furthermore, various functions of the mobile communication device **20** may be implemented in hardware and/or in software, including in one or more signal processing and/or application-specific integrated circuits.

The components and arrangements shown in FIG. **2**A for both the server **80** and the mobile communication device **20** are not intended to limit the disclosed embodiments. As will be appreciated by a human user skilled in the art having the benefit of this disclosure, numerous variations and/or modifications may be made to the depicted configuration of the server **80**. For example, not all the depicted components may be essential for the operation of server **80** in all cases. Any component may be located in any appropriate part of the server **80**, and the components may be rearranged into a

variety of configurations while providing the functionality of the disclosed embodiments. For example, some servers may not include all the elements in I/O system **218**. Similarly, not all the depicted components may be essential for the operation of the mobile communication device **20** in all cases. For example, some types of mobile communication devices may include only part of the depicted sensors and include sensors which are not depicted.

Referring now to FIG. **2**B, the block diagram of an exemplary phone location unit **60** is depicted.

In one embodiment, Phone Location Unit **60** may comprise a processing unit **602** which may control the Phone Location Unit **60**, at least one RF receiver **603** coupled **609** to the processing unit **602** and coupled to a plurality of antennas **604**A-**604**D, an inertial measurement unit (IMU) **607** such as an accelerometer, magnetometer or, gyroscope, a buzzer **608** for providing audio notifications, and a DC/DC converter **606** that may provide the required power to each of the Phone Location Unit **60** functions. The coupling **609** between the at least one RF receiver **603** and processing unit **602** may consist of a digital data bus, comprising sampled data from an Analog-to-Digital component (not shown) in the receiver **603**. The A/D samples may be processed by the processing unit **602** to detect and locate the source of the received signals **613**.

According to some embodiments, the processing unit **602** may also interface with a memory **610**. The memory device **610** may include high-speed random-access memory and/or non-volatile memory such as one or more magnetic disk storage devices, one or more optical storage devices, and/or flash memory (e.g., NAND, NOR). The memory device **610** may store an operating system, such as Android, iOS, MS Windows, Linux, or any other embedded operating system. The operating system may include instructions for handling basic system services and for performing hardware-dependent tasks. In some implementations, the operating system may be a kernel (e.g., Linux kernel).

The memory device **610** may also store communication instructions to facilitate communicating with one or more additional devices, one or more computers, and/or one or more servers. The memory device **610** may include: graphical user interface instructions to facilitate graphic user interface processing; sensor processing instructions to facilitate sensor-related processing and functions; signal processing instructions to facilitate signal processing algorithms and functions; electronic messaging instructions to facilitate electronic-messaging related processes and functions; web browsing instructions to facilitate web browsing-related processes and functions; media processing instructions to facilitate media processing-related processes and functions; GPS/navigation instructions to facilitate GPS and navigation-related processes and instructions; and/or other software instructions to facilitate other processes and functions.

In one embodiment, the Analog-to-Digital (A/D) component is part of the RF receiver unit **603** wherein analog signals are provided by the RF receiver **603** through the coupling **609**. In one embodiment each coupling **609** may use a plurality of lanes (e.g., **2** lanes) in order to reduce the data rate at every single lane.

In some embodiments, the DC/DC converter may also be connected **611** to an external power source. According to one embodiment, the external power source is a vehicle's battery.

In one embodiment, a mobile communication device **20** (not shown) within a defined volume (e.g., vehicle's cabin) in which the antennas **604**A-**604**D are deployed and operative to receive wireless signals **613** transmitted by the mobile communication device **20**, may be located in a predetermined area (e.g., driver's seat area) inside the defined volume.

According to one embodiment, the antennas **604**A-**604**D may be installed in different places in the volume in order to create space diversity to the wireless signals **613** transmitted within the volume. The places in which those antennas **604**A-**604**D are installed may have a significant influence on the phone location unit **60** performance and to its ability to locate a mobile communication device **20** in a predetermined area (e.g., driver's seat area or passenger's area). According to one embodiment, the placement of the antennas **604**A-**604**D may be optimized to locate mobile communication devices **60** in the driver's seat area.

According to one embodiment, the Phone Location Unit **60** may further comprise an embedded short-range wireless link (e.g., an IEEE802.11a/b/g/n/ac/ad WLAN and/or BT/BLE transceiver) **630**. The short-range transceiver **630** may comprise an antenna (internal or external) **631** and may be connected **632** to the processing unit **602**. In one embodiment, the short-range transceiver **630** may communicate **633** with a mobile communication device in communication range. According to one embodiment, the short-range communication **633** may be performed through an IEEE802.11a/b/g/n/ac/ad Access Point, hub, gateway or the like (not shown).

In one embodiment, the at least one RF receiver **603** may be programmed to receive signals in the frequency band of the wireless signals **613** transmitted by the mobile communication device **20**. According to one embodiment, the RF receiver **603** may be connected one at a time to each of the antennas **604**A-**604**D. This connection may be performed by an RF switch (not shown), typically with a low insertion loss and low noise figure. The architecture of the RF receiver **603** may differ among different implementations of the Phone Location Unit **60**. In one embodiment, it may comprise a low noise amplifier (LNA), bandpass filters, a synthesizer, a mixer, an IQ demodulator, low pass filters, and analog-to-digital converters. The sampled baseband signals may be transferred **609** to a processing unit **602** to be further processed.

The processing unit **602** may the collection process until enough signal samples from each of the antennas **604**A-**604**D are collected in order to estimate the location of the mobile communication device **20** in the volume.

According to one embodiment of the present invention, the Phone Location Unit **60** may utilize one of the following methods or any combination of them, to locate the position of the mobile communication device **20** in a defined volume and/or detect its presence in a predetermined area:

- Received Signal Strength Indicator (RSSI): Using the RSSI at each antenna to estimate the wireless device distance to that antenna and then using triangulation techniques. This method may utilize the ratio of the RSSI at each antenna pair **604**A-**604**D.
- Channel fingerprinting: Generating a radio map of the volume comprising RF-parameters signatures at each of the antennas **604**A-**604**D. Then estimating the mobile communication device position by correlating measured values of RF parameters at each antenna to fingerprints values in the radio map. Fingerprinting methods may utilize Power Level (RSSI) based methods and Delay-spread based methods.
- Time Differential-Of-Arrival (TDOA): Estimating the position of the mobile communication device **20** by multilateration of hyperbolae. For example, the Phone Location Unit **60** may comprise four antennas and two

RF receivers, wherein the two RF receivers are selectively connected to a pair of antennas for a TDOA measurement.

Round-Trip time (RTT): Estimating the position of the mobile communication device **20** by multilateration of circles. For example, the Phone Location Unit **60** may comprise four antennas and one RF transceiver, wherein the RF transceiver is selectively connected to an antenna **604**A-**604**D for an RTT measurement.

Angle-Of-Arrival (AOA)/Direction-Of-Arrival (DOA) technology: Estimating the angle or direction of arrival at each of the antennas of wireless signals **613** transmitted by the mobile communication device and then using this information to locate the device.

The above-described networks can be implemented in a packet-based network, a circuit-based network, and/or a combination of a packet-based network and a circuit-based network. Packet-based networks can include, for example, the Internet, a carrier internet protocol (IP) network (e.g., local area network (LAN), wide area network (WAN), campus area network (CAN), metropolitan area network (MAN), home area network (HAN), a private IP network, an IP private branch exchange (IPBX), a wireless network (e.g., radio access network (RAN), IEEE802.11a/b/g/n/ac/ad network, IEEE802.15.4, IEEE802.16 network, general packet radio service (GPRS) network, HiperLAN), and/or other packet-based wireless networks, a wireless network (e.g., RAN, Bluetooth®, code-division multiple access (CDMA) network, time division multiple access (TDMA) network, global system for mobile communications (GSM) network, EDGE, and GPRS), 3G, LTE or 5G, and/or other circuit-based networks.

FIG. **3** is a high-level flowchart illustrating a method for classifying the type of interaction of a mobile communication device in accordance with embodiments of the present invention. Step **302** includes measuring by a PLU, the RSSI of RF signals from a mobile communication device received at a plurality of antennas in a defined volume. Step **304** includes measuring by a PLU, the angle of arrival and/or the time of arrival of RF signals from a mobile communication device received at a plurality of antennas in a defined volume. These steps may occur simultaneously or can be sequential steps. The measurements are processed by a PLU **310** leading to step **320** which includes determining the position of the at least one mobile communication device relative to a frame of reference of the defined volume.

Step **332** may include obtaining the reading from a non-RF sensor located on one of a plurality of the mobile communication devices within the defined volume. Step **332** is repeated over time to yield time series **332**A of the readings. Step **334** may include obtaining a reading from a non-RF sensor (i.e., a non-RF sensor does not use RF signals for its sensing operation but can use RF signals to communicate and transfer its measurements to another device) external to the plurality of the mobile communication devices within the defined volume. Step **334** is repeated over time to yield time series **334**A of the readings. Step **336** may include obtaining a reading from a non-RF sensor located in the Phone Location Unit. Step **336** is repeated over time to yield time series **336**A of the readings These steps may occur simultaneously or in any order, wherein in some cases, only a subset of them may occur.

Some or all of the readings of the sensors of steps **332**, **334**, and **336**, and their respective time series **332**A, **334**A, and **336**A, together with the position as calculated by the PLU at step **320**, are fed into a classifier **340**, leading to step **350** which includes classifying the type of interaction of the mobile communication device into one of a plurality of predefined types of interaction.

According to some embodiments of the present invention, the classification by the classifier is carried out by assigning to the at least one mobile communication device a respective probability to at least one type of interaction selected from a plurality of types of interaction. According to some embodiments, the classification algorithm may assign a probability to a plurality of predefined types of interaction and then select the one that has the highest probability. According to some embodiments, this classification may involve history measurements and classifications, user's behavior, and other parameters.

According to some embodiments of the present invention, the types of interaction comprise at least one of no-engagement, audio engagement, visual engagement, audio-visual engagement; routine activity; and non-routine activity.

According to some embodiments, the type of interaction classification further includes information about a human user interacting with the mobile communication device. For example, there is a significant difference if a mobile communication device in texting mode is interacting with a bus driver, or a passenger seated in a back seat.

According to some embodiments of the present invention, the obtaining at least one sensor measurement related to the at least one mobile communication device is from a motion sensor, said sensor providing information related to the vehicle's speed and wherein the vehicle's speed is factored in classifying the likelihood of the type of interaction, wherein for a mobile communication device located in the driver's area, a higher speed infers a higher probability of non-engaged type of interaction or a type of interaction not involving the manual intervention of the user.

According to some embodiments of the present invention, inside the vehicle there is at least one human user, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a proximity sensor, said proximity sensor providing information on the proximity between the at least one mobile communication device and the at least one human user, and wherein the proximity is factored in classifying the likelihood of the type of interaction, wherein a closer proximity infers a higher probability of an on-call type of interaction.

According to some embodiments of the present invention, inside the vehicle, there is at least one human user, and wherein the vehicle comprises at least one seat with a pressure sensor indicating that said seat is occupied by the at least one human user, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a seat pressure sensor and wherein the seat pressure sensor indication is factored in classifying the likelihood of the type of interaction, wherein a positive indication of a seat pressure sensor infers a higher probability of a use of a mobile communication device by a human user occupying that seat.

According to some embodiments of the present invention, inside the vehicle there is at least one human user, and wherein the at least one human user is sensed by at least one vital signs sensor, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from at least one vital signs sensor and wherein a vital signs measurement is factored in classifying the likelihood of the type of interaction, wherein a level of vital signs outside (e.g., above or below) a certain

threshold or limit infers a higher probability of a non-idle type of interaction of the at least one mobile communication device.

According to some embodiments of the present invention, the inventors have discovered that while sensor fusion of the non-RF sensors can be used in order to improve the accuracy of the positioning of the mobile communication device within the volume, the sensor fusion can be used together with the positioning of the PLU in order to classify the mobile communication device into a plurality of pre-defined types of interaction. This can be done either by classic classifiers or using machine learning techniques that involved training a model with datasets.

FIG. **4** is a graph showing an implementation of an N dimensions classifier in accordance with some embodiments of the present invention. Multi-dimensional space **400** denotes the sensor measurement space in which readings of the location from the PLU (e.g., in the form of a vector denoting distance from the driver's canopy) as well as other sensor readings. By way of a non-limiting example, one further dimension may be a touch screen sensor denoting the level of activity recorded by the touch screens of the mobile communication devices. Yet a further dimension may be vital signs sensors such as heart rate sensors embedded in the mobile communication device. It is understood that many more dimensions in the sensors space **400** may be used and calculated.

In accordance with some embodiments of the present invention, following a training session of datasets associated with measurements time series from relevant sensors, portions of the sensors space **400** can be allocated and designated as specific use cases and types of interaction associated with the one or more mobile communication devices within the volume.

For example, a portion of sensors space **400** where the distance from the driver's canopy is short, there is little activity of vital signs, and no touch screen activity of the mobile communication device infers that the driver is on his or her way to work with little distraction **404**. Same readings but with a high level of touch screen activity of the mobile communication device infer that the driver is navigating, possibly on a trip **402**. In order to validate these classifications, the time series of the GPS readings of the journey of the vehicle may be used to check re-reoccurring journeys.

Similarly, a high level of vital signs activity combined with a medium level of touchscreen activity and a long distance from the driver's canopy may infer that the phone is being held by a child on his or her way to school **406**. Lower activity of vital signs may infer a passenger engaged with texting **408**.

It is understood that many more types of interaction may be mapped to a sensors space **400** having multiple sensor dimensions and some of the portions may be overlapping requiring to make classification decisions based on more parameters and other sensor readings. Repeating the measurements and using time series may significantly increase the ability to detect trends in the user activity as well as cloudify the profile of the human using the mobile communication device.

It is further understood that some embodiments of the present invention may be embodied in the form of a system, a method, or a computer program product. Similarly, some embodiments may be embodied as hardware, software, or a combination of both. Some embodiments may be embodied as a computer program product saved on one or more non-transitory computer-readable medium (or mediums) in the form of computer-readable program code embodied thereon. Such non-transitory computer-readable medium may include instructions that when executed cause a processor to execute method steps in accordance with embodiments. In some embodiments, the instructions stored on the computer-readable medium may be in the form of an installed application and in the form of an installation package.

Such instructions may be, for example, loaded by one or more processors and get executed. For example, the computer-readable medium may be a non-transitory computer-readable storage medium. A non-transitory computer-readable storage medium may be, for example, an electronic, optical, magnetic, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any combination thereof.

Computer program code may be written in any suitable programming language. The program code may execute on a single computer system, or on a plurality of computer systems.

One skilled in the art will realize the invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting of the invention described herein. Scope of the invention is thus indicated by the appended claims, rather than by the foregoing description, and all changes that come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

In the foregoing detailed description, numerous specific details are set forth in order to provide an understanding of the invention. However, it will be understood by those skilled in the art that the invention can be practiced without these specific details. In other instances, well-known methods, procedures, and components, modules, units, and/or circuits have not been described in detail so as not to obscure the invention. Some features or elements described with respect to one embodiment can be combined with features or elements described with respect to other embodiments.

The invention claimed is:

1. A method of classifying a type of interaction between a human user and at least one mobile communication device within a defined volume, based on at least one sensor, wherein inside the defined volume there is at least one human user interacting with the at least one mobile communication device and wherein the type of interaction the method comprising:

determining a position of the at least one mobile communication device relative to a frame of reference of the defined volume, based on at least one of: angle of arrival, time of flight, or received intensity of radio frequency (RF) signals transmitted by the at least one mobile communication device and received by a phone location unit located within the defined volume and comprising a transceiver and antennas and further configured to wirelessly communicate with the at least one mobile communication device;

obtaining at least one sensor measurement related to the at least one mobile communication device, from a sensor located on at least one of: the at least one mobile communication device, within the defined volume, or outside of the defined volume, wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a proximity sensor, said proximity sensor providing information on a proximity between the at least one mobile communication device and at least one human user;

repeating the obtaining over time, to yield at least one time series of sensor readings; and

increasing the position accuracy of the at least one mobile communication device relative to the frame of reference based on the at least one sensor measurement related to the at least one mobile communication device, to yield an improved position; and

using a computer processor to classify the type of interaction into one of a plurality of predefined types of user-interactions, based on the improved position and the at least one time series of sensor readings, wherein the proximity is factored in classifying the likelihood of the type of user-interactions, wherein a closer proximity infers a higher probability of an audio engagement type of interaction.

2. The method according to claim **1**, wherein the defined volume is a vehicle.

3. The method according to claim **1**, wherein the classification by the computer processor is carried out by assigning to the interactions between the human user and the at least one mobile communication device a respective likelihood, to at least one type of interaction selected from a plurality of types of interaction.

4. The method according to claim **3**, wherein the obtaining the sensor measurement related to the at least one mobile communication device is from at least two inertial measurement units (IMU), wherein at least one of the IMU is located on the mobile communication device and at least one of the IMUs is located on the vehicle, and wherein a differential measurement of the IMU is used to deduce internal movement of the at least one mobile communication device within the vehicle.

5. The method according to claim **3**, wherein the position of the mobile communication unit within the defined volume is further determined to be in the vehicle's driver area, wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a motion sensor, said sensor providing information related to the vehicle's speed and wherein the vehicle's speed is factored in classifying the likelihood of the type of interaction, wherein for a mobile communication device located in the driver's area, a higher speed infers a higher probability of no engagement type of interaction.

6. The method according to claim **3**, wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from vital signs sensor, said vital signs sensor providing information on the level of physiological activity of the at least one human user using the mobile communication device, and wherein the level of vital signs is factored in classifying the likelihood of the type of interaction, wherein a higher level of vital signs activity infers a higher probability of audiovisual engagement.

7. The method according to claim **3**, wherein the vehicle comprises at least one seat with a pressure sensor indicating that said seat is occupied by the at least one human user, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a seat pressure sensor and, wherein a positive indication of a seat pressure sensor infers a higher probability of a use of a mobile communicating device by the at least one human user occupying said seat.

8. The method according to claim **7**, wherein the seat pressure sensor indication together with the proximity sensor measurement between the mobile communication device and the human user increase the probability to estimate whether a phone call is performed by a driver with the mobile communication device on-hand.

9. The method according to claim **3**, wherein the at least one human user is sensed by at least one vital signs sensor, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from at least one vital signs sensor and wherein a vital signs measurement is factored in classifying the likelihood of the type of interaction, wherein a level of vital signs outside a certain threshold or limit infers a higher probability of an engaged type of interaction.

10. The method according to claim **1**, wherein the type of interaction comprises at least one of: no-engagement, audio engagement, visual engagement, audio-visual engagement; routine activity; and non-routine activity.

11. The method according to claim **1**, wherein the improved position and the at least one time series of sensor readings comprise a combination of said determined position of at least one mobile communication device and said proximity sensor measurement.

12. A system for classifying a type of interaction between a human user and at least one mobile communication device within a defined volume, based on at least one sensor, the system comprising:

a phone locating unit configured to determine a position of the at least one mobile communication device relative to a frame of reference of the defined volume, based on at least one of: angle of arrival, time of flight, or received intensity of radio frequency (RF) signals transmitted by the at least one mobile communication device and received by the phone location unit located within the defined volume and comprising a transceiver and antennas and further configured to wirelessly communicate with the at least one mobile communication device;

a plurality of non-RF sensors configured to repeatedly obtain at least one sensor measurement related to the at least one mobile communication device, from a sensor located on at least one of: the at least one mobile communication device, within the defined volume, or outside of the defined volume, to yield at least one time series of sensor readings, wherein the at least one sensor measurement related to the at least one mobile communication device is obtained from a proximity sensor, said proximity sensor providing information on a proximity between the at least one mobile communication device and at least one human user; and

a computer processor configured to:

increase a position accuracy of the at least one mobile communication device relative to the frame of reference based on the at least one sensor measurement related to the at least one mobile communication device, to yield an improved position; and

classify the at least one type of interaction into at least one of a plurality of predefined types of interaction, based on the improved position and the at least one time series of sensor readings, wherein the proximity is factored in classifying the likelihood of the type of user-interactions, wherein a closer proximity infers a higher probability of an audio engagement type of interaction.

13. The system according to claim **12**, wherein the defined volume is a vehicle.

14. The system according to claim **12**, wherein the classification by the computer processor is carried out by assigning to the interactions between the human user and the at least one mobile communication device a respective likelihood, to at least one type of interaction selected from a plurality of types of interaction.

15. The system according to claim 14, wherein the obtaining the sensor measurement related to the at least one mobile communication device is from at least two inertial measurement units (IMU), wherein at least one of the IMU is located on the mobile communication device and at least one of the IMUs is located on the vehicle, and wherein a differential measurement of the IMU is used to deduce internal movement of the at least one mobile communication device within the vehicle.

16. The system according to claim 14, wherein the position of the mobile communication unit within the defined volume is further determined to be in the vehicle's driver area, wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a motion sensor, said sensor providing information related to the vehicle's speed and wherein the vehicle's speed is factored in classifying the likelihood of the type of interaction, wherein for a mobile communication device located in the driver's area, a higher speed infers a higher probability of no engagement type of interaction.

17. The system according to claim 14, wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from vital signs sensor, said vital signs sensor providing information on the level of physiological activity of the at least one human user using the mobile communication device, and wherein the level of vital signs is factored in classifying the likelihood of the type of interaction, wherein a higher level of vital signs activity infers a higher probability of audiovisual engagement.

18. The system according to claim 14, wherein the vehicle comprises at least one seat with a pressure sensor indicating that said seat is occupied by the at least one human user, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from a seat pressure sensor and wherein the seat pressure sensor indication is factored in classifying the identity of the human user, wherein a positive indication of a seat pressure sensor infers a higher probability of a use of a mobile communicating device by the at least one human user occupying said seat.

19. The system according to claim 18, wherein the seat pressure sensor indication together with the proximity sensor measurement between the mobile communication device and the human user increase the probability to estimate whether a phone call is performed by a driver with the mobile communication device on-hand.

20. The system according to claim 14, wherein the at least one human user is sensed by at least one vital signs sensor, and wherein the obtaining at least one sensor measurement related to the at least one mobile communication device is from at least one vital signs sensor and wherein a vital signs measurement is factored in classifying the likelihood of the type of interaction, wherein a level of vital signs outside a certain threshold or limit infers a higher probability of an engaged type of interaction.

21. The system according to claim 12, wherein the type of interaction comprises at least one of: no-engagement, audio engagement, visual engagement, audio-visual engagement; routine activity; and non-routine activity.

22. The system according to claim 12, wherein the improved position and the at least one time series of sensor reading comprise a combination of said determined position of at least one mobile communication device and said proximity sensor measurement.

23. A non-transitory computer-readable medium for classifying a type of interaction between a human user and at least one mobile communication device within a defined volume, based on at least one sensor, the computer-readable medium comprising a set of instructions that when executed cause at least one computer processor to:

determine a position of the at least one mobile communication device relative to a frame of reference of the defined volume, based on at least one of: angle of arrival, time of flight, or received intensity of radio frequency (RF) signals transmitted by the at least one mobile communication device and received by a phone location unit located within the defined volume and comprising a transceiver and antennas and further configured to wirelessly communicate with the at least one mobile communication device;

obtain at least one measurement related to the at least one mobile communication device, from a sensor located on at least one of: the at least one mobile communication device, within the defined volume, or outside of the defined volume;

repeat the obtaining over time, to yield at least one time series of the sensor readings; and

increase a position accuracy of the at least one mobile communication device relative to the frame of reference based on the at least one sensor measurement related to the at least one mobile communication device, to yield an improved position, wherein the at least one sensor measurement related to the at least one mobile communication device is obtained from a proximity sensor, said proximity sensor providing information on a proximity between the at least one mobile communication device and at least one human user;

process the sensor readings and the position of the at least one mobile communication device to yield at least one type of interaction; and

classify the at least one interaction into at least one of a plurality of predefined types of interaction, based on the improved position and the at least one time series of sensor readings, wherein the proximity is factored in classifying the likelihood of the type of user-interactions, wherein a closer proximity infers a higher probability of an audio engagement type of interaction.

24. A server for classifying a type of interaction of at least one mobile communication device within a defined volume, based on at least one sensor, the server comprising:

a network interface configured to receive, from a phone location unit, a position of the at least one mobile communication device relative to a frame of reference of the defined volume, based on at least one of: angle of arrival, time of flight, or received intensity of radio frequency (RF) signals transmitted by the at least one mobile communication device and received by the phone location unit located within the defined volume and comprising a transceiver and antennas and further configured to wirelessly communicate with the at least one mobile communication device;

a memory interface configured to store at least one measurement related to the at least one mobile communication device, from a sensor located on at least one of: the at least one mobile communication device, within the defined volume, or outside of the defined volume;

a processing device configured to repeat the obtaining over time, to yield at least one time series of the sensor readings and increase a position accuracy of the at least one mobile communication device relative to the frame of reference based on the at least one sensor measurement related to the at least one mobile communication device, to yield an improved position, wherein the at

least one sensor measurement related to the at least one mobile communication device is obtained from a proximity sensor, said proximity sensor providing information on a proximity between the at least one mobile communication device and at least one human user; and

to classify the at least one interaction into at least one of a plurality of predefined types of interaction, based on the improved position and the at least one time series of sensor readings, wherein the proximity is factored in classifying the likelihood of the type of user-interactions, wherein a closer proximity infers a higher probability of an audio engagement type of interaction.

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